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Collaborative Language Learning in Immersive Virtual Worlds: Competence-based Formative Feedback and Open Learner Modeling

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Abstract

The uptake of information and communication technologies in the classrooms is a key trend over the past years and decades. Teachers are using Moodle courses, e-Portfolios, Google Docs, perhaps learning games or virtual worlds such as OpenSim for educational purposes. A second trend pushes towards a formatively inspired assessment and feedback, often combined with attempts of educational data mining and learning analytics. In this paper, we present a role model for teaching English as a second language using OpenSim and a tool that enables teachers to perform real-time learning analytics and direct formative feedback and interventions in the virtual learning session. Also we present an approach to aggregate and store the learning information into open learner models.

Keywords: *Learning Analytics, Competence-based Knowledge Space Theory, Open Learner Models, Virtual Worlds, OpenSim*

1. Introduction

Formative assessment and feedback is a key driver of successful education and there is, no doubt, significant hype over it in the educational community [1]. Especially new technologies enter the field, aiming at supporting teachers in gathering large scale data, aggregating and analyzing them, and perhaps most importantly, to visualize and present the outcomes of analyses in a way that is most useful and beneficial for the learners. Certainly, such attempt is not new. (Good) teachers of all times have focused on supporting their students to the best possible extent and to bring them forward - to identify knowledge/competence gaps to inform learners and to facilitate a deeper understanding. Particularly in times where the educational community and (above all) policy makers (e.g., [2]) increasingly acknowledges the importance of meta-abilities, critical skills, and the so-called “21st century skills”, formative education becomes a necessity rather than a nice to have.

This trend is accompanied with the daily growing mass of data available about students. Information and communication technologies (ICT) enter the classrooms more and more, various online sources are linked together and are used for educational purposes, and specific educational software and technical devices (e.g., tablets and smartphones) are used to enrich teaching and learning. Thus it is not surprising that the communities of learning analytics (LA) and educational data mining (EDM) growing hand in hand with the state-of-the-art in formative feedback. The growing amount of data available for teachers has certain downsides. The more data (and information) is available about a learner, the more time consuming and difficult is it to handle the data and to identify (formative) meaning in the data. The consequence is that, when we want to make use of the “big data”, we need to equip teachers and educators with smart software tools and smart methods to perform effective and tailored learning analytics and educational data mining.

2. Formative Assessment, Learning Analytics, Open Learner Models

Formative assessment enables teachers to enrich their daily routines of lesson, exam, announcement of grades, new lesson, new exam, etc. with a more individual focus and a more in-depth insight into learning processes. Formative assessment, in essence, means identifying the



momentary differences between current knowledge states and the educational target states of learners with the prime goal of promoting an effective competence development on an individual basis [3]. “Formative” means identifying ways to utilizing the value of proper communication between learners and teachers, to strengthen an active role of learners, to optimize teaching/learning on an individual basis, and to acknowledge the psycho-social value of assessment/appraisal [4]. According to Gijbels and Dochy[5], key factors of formative assessment are (i) appropriate, effective, and tailored feedback to learners, (ii) assigning responsibility for one’s own learning, (iii) discovering the need of learners to evaluate and appraise themselves appropriately, (iv) adjusting the teaching activities according to the insights of assessment, and finally (v), acknowledging the motivational aspect inherent to assessment and appraisal and the related impact on self-esteem, self-perception, and well-being. Analyses such as those of Black and Wiliam [6], Marzano [7], or Wiliam [8] provide evidence that formatively inspired teaching is superior to conventional approaches.

As stressed initially, new challenges and at the same time great new possibilities for researchers and educators occur through the vast and still growing amount of available data that might hold educational relevance. A field that is concerned with finding educationally relevant meaning in large scale data sets is learning analytics (LA) and educational data mining (EDM). The focus areas of these communities seem to be slightly different but, in principle, they follow similar goals, namely the improvement of educational technology and the evaluation of pedagogically sound instructional designs [9].

EDM, in essence, has its origins in multiple research areas such as statistics, data mining, machine learning, or computational modeling. The goal is to automatically and intelligently discover patterns and models from extensive datasets about learners [10].

LA specifically targets at supporting pedagogical activities by providing assistance to teachers in practically relevant questions (e.g., the quality of learning material or the engagement of students in specific exercises). Information gained through LA tools can be used to evaluate pedagogically sound instructional designs within classroom settings. In most cases this focuses mainly on monitoring learner actions and their interactions with learning tools and learning peers [11]. A specific focus area in the context of LA is visualizing knowledge/competence a, earning progress, and behavioral information. For example, visualization “dashboards” have been developed [12], which include a set of different graphing and charting features.

In general, learner models hold information about a student’s learning including the current knowledge, competencies, misconceptions, goals, affective states, etc. This information is continuously updated on the basis of multiple input sources. A recent trend is to disclose the information to the various stakeholders such as learners, teachers, parents, administrators, evaluators, or policy makers). The prime objective of such open learner models (OLM) is to communicate educationally relevant information, to raise awareness, to support reflection, and to encourage more responsibility of one’s own learning. As LA tools, an important aim is to help teachers to better understand their student’s but also the impact of their own teaching activities [13]. A key factor in the context of OLM is to provide appropriate and easy to understand visualizations tailored to a specific stakeholder. The most common visualizations used include skill meters, concept maps and hierarchical tree structures. Recently, tree map overview-zoom-filter approaches to open learner modeling have also started to appear, as have tag/word clouds [14], and sunburst views [15].

3. Formative Assessment and Feedback in Virtual Worlds

Equally broad and promising as the recent interest in LA and FA is the interest in using virtual worlds, perhaps in form of educational games, for educational purposes. A virtual world is a computer-based, simulated environment where individuals assume a virtual identity called an avatar. Avatars inhabit the virtual worlds and interact with each other via computer-based chat, or more recently, voice. Virtual worlds are common in multiplayer online games, virtual environments (such as Second Life), and role-playing games (such as Lineage). Due to increasing broadband internet access, virtual worlds are rapidly emerging as an alternative means to the real world for communicating, collaborating, and organizing activity. In the past years – primarily in response to the removal of the educator discount by Linden Lab, OpenSim (www.opensimulator.org) has been increasing in popularity particularly among educators. OpenSim is an open source multi-platform, multi-user 3D application server that enables individuals and firms across the globe to customize their virtual worlds based on their technology

preferences. The project is powered by the efforts of the community members, who devote their time and energy to the development processes. The project has a global reach and the community hosts a very diverse group of actors: independent users, freelance developers, non-profit organizations (e.g., universities), and both small and large for-profit firms. The OpenSim project has a 3D aspect that facilitates a strong sense of immersion for both its developers and users, setting the project apart from traditional open-source projects. Since the project develops around such a strong communications medium, there are many contributing to and using OpenSim, who are very passionate about virtual environments and its power as a platform for social exchange. This gives the project a more personal spin for these people.

In the context of a meaningful uptake of ICT in more or less formal educational settings virtual worlds offer a broad spectrum of educational options. For example, such environments can be used for collaboration, for communication but also for a gamification of learning. Another key aspect is the beguilingly simple fact that virtual worlds are not constrained by real world physics. While this may appear to be self-evident, it is worth consideration when imagining and planning what one can do in these virtual environments. For example, a resident of the solar system can ‘stand’ on the rings of a virtual Saturn to learn about astronomy or a molecule could be demonstrated in large and in a manipulative format to teach chemistry.

In the light of formative assessment, LA, and EDM, virtual worlds – equally to serious games – the characteristic that they can generate a massive amount of activity and performance data about learners and, therefore, provide teachers with valuable information about learning related aspects, motivational states, or social relationships within a class. However, to utilize such advantages, it is necessary to empower teachers to follow and understand what is going on in the virtual world. Moreover, it is necessary to transform the mere data bits into insight into students’ learning.

4. Language Teaching in Virtual Worlds: An Example

In the context of the NEXT-TELL (www.next-tell.eu) project, a four year integrated multi-national research project funded by the European Commission that aims at developing a smart ICT infrastructure for European classrooms (www.next-tell.eu), we developed a learning scenario for learning English in form of a multiplayer adventure in OpenSim.

The idea is that an entire class logs into the virtual world and forms small teams. The playground for this adventure is Chatterdale (Figure 1), an (isolated) island in OpenSim developed and hosted by 3DLES (<http://3dles.com/en/>). The teams are supposed to solve a mysterious riddle: Why is the town they find abandoned? Where are all the people? There are only a few characters left (e.g., a drunkard or a priest) who can provide the teams with foretelling and throughout the world various hints are hidden. Accomplishing this scavenger hunt, the teams must read and listen to English texts and must understand the (often complex) meaning and must identify the main points. A highly motivational, competitive element is a reward for the team who solves the riddle first. From a pedagogical perspective, the scenario is designed around the so-called CEFR skills, a common specification of second language competencies (cf. <http://www.cambridgeol.org/about/standards/cefr.html>).

In order to achieve a competence-centered and formatively inspired teaching, a virtual learning scenario such as Chatterdale is a perfect teaching environment because it combines experiential, active, constructivist learning, with the need to directly apply the competencies in a meaningful setting, not least receiving direct feedback (e.g., by progressing with the scavenger hunt or by feedback of virtual educational entities). In that sense, a playful use of virtual worlds enables designing instructionally brilliant lessons, grounding for example on the important “First Principles of Education”, as stated by famous M. David Merrill [16]. The principles are (1) demonstration, (2) application, (3) activation of prior knowledge, (4) integration of new information into the mental and physical world of the learner, and (5) an orientation to meaningful tasks.

As mentioned before, the great advantage but a critical downside of such a virtual scenario is the massive amount of relevant educational data being produced and the inability of teachers to monitor, record, aggregate the information in a formative sense in order to generate a fair and correct model of a learner’s activities and competencies – without the support of smart software solutions enabling a sufficiently deep level of LA. In other words, imagine an entire school class with 25 students; all are entering a large virtual world and disperse quickly all over this world. The teacher has almost no chance to keep track about what is going on in the world, who is active or inactive, who is communicating to whom in which manner, etc.



Figure 1. Screenshots of the Chatterdale scenario

One option is log file data. Usually, virtual environments such as OpenSim provide detailed log files for specific sessions. Unfortunately, the amount of information, stored in such log files, is massive and it takes software to analyze the log files – in an educationally meaningful way. This is the prerequisite that the activities and the performance in the virtual worlds can really contribute to a formative assessment and thus a tailored support of students.

5. *ProNIFA: A LA Tool on the Foundations of CbKST*

ProNIFA is a tool to support teachers in LA and formative assessment. The name stands for probabilistic non-invasive formative assessment and, in essence, establishes a handy user interface for related data aggregation and analysis services and functions. Conceptually, the functions are based on Competence-based Knowledge Space Theory (CbKST), originally established by Jean-Paul Doignon and Jean-Claude Falmagne [17], which is a well elaborated set-theoretic framework for addressing the relations among problems (e.g., test items). It provides a basis for structuring a domain of knowledge and for representing the knowledge based on prerequisite relations. While the original idea considered performance only (the behavior; for example, solving a test item), extensions of the approach introduced a separation of observable performance and latent, unobservable competencies, which determine the performance [18].

CbKST assumes a finite set of more or less atomic competencies (in the sense of some well-defined, small scale descriptions of some sort of aptitude, ability, knowledge, or skill) and a prerequisite relation between those competencies. A prerequisite relation states that competency a (e.g., to multiply two positive integers) is a prerequisite to acquire another competency b (e.g., to divide two positive integers). A learner's competence state is described by a subset of competencies. Due to the prerequisite relations between the competencies, not all subsets are admissible competence states. By utilizing interpretation and representation functions the latent competencies are mapped to a set of tasks (or test items) covering a given domain. By this means, mastering a task correctly is linked to a set of necessary competencies and, in addition, not mastering a task is linked to a set of lacking competencies. This assignment induces a performance structure. Recent versions of the conceptual framework are based on a probabilistic mapping of competencies and performance indicators, accounting for making lucky guesses or careless errors. This means, mastering a task correctly provides the evidence for certain competencies and competence states with a certain probability.

ProNIFA retrieves performance data (e.g., the results of a test or the activities in a virtual environment) and updates the probabilities of the competencies and competence states in a domain. When a task is mastered, all associated competencies are increased in their probability, vice versa, failing in a task decreases the probabilities of the associated competencies. A distinct feature in the context of formative assessment is the multi-source approach. ProNIFA allows for connecting the LA algorithms to a broad range of sources of evidence. This refers to direct interfaces (for example to Google Docs) and it refers to connecting, automatically or manually, to certain log files. Using this level of connectivity, multiple sources can be merged and can contribute to a holistic analysis of learners' achievements and activity levels. The interpretation of the sources of evidence occurs depending on a-priori specified and defined conditions, heuristics, and rules, which associate sets of available and lacking competencies to achievements exhibited in the sources of evidence. The idea is to define certain conditions or states in a given environment (regardless if it is a Moodle test or a status of a problem solving process in a learning game). Examples for such conditions may be the direction, pace, and altitude a learner is flying with a space ship in an adventure game or a combination of correctly and incorrectly ticked multiple choice tasks in a regular online school test. The specification of such state can occur in multiple forms, ranging from simply listing test items and the correctness of the items to complex heuristics such as the degree to which an activity reduced the 'distance' to the solution in a problem solving process. The next step is to assign a set of competencies that can be assumed to be available and also lacking when a certain state occurs. This assumption can be weighted with the strength of the probability updates. In essence, this approach equals the conceptual framework of micro adaptivity as, for example, described by [19].

6. Working with Virtual Worlds

Related to the Chatterdale English learning scenario for OpenSim, we developed a chat log analysis module (Figure 2), the so-called *Teacher Control Center*. The module allows using a course with a set of assigned students and a set of involved competencies (in this particular case 6 of aforementioned CEFR skills); in a second step the teacher may apply a set of rules to interpret the log files. The possibilities range from simple counting of certain events up to using scripting code to identify competencies. In the following box an example is given; this rule defines a time-based quest. The students have to listen to what the old man says; his talk finishes with "... , now go there!". The actual target is a box with a hidden letter in a hotel. If a student, indicated by "<NAME>", has understood the talk and manages to get to the hotel within 5 minutes, the system takes this as an indicator that the student has competence number 2 and consequently increases the probability in the competence model for this student by the value 0.2. In the same manner competencies could be decreased in the probability as well.

On such basis, the entire log file with the data about all students is analyzed and the competence models for all students are updated incrementally. As a result, a teacher can access a broad range of information of the OpenSim session, the activities and learning performance. In Figure 2, some examples are shown. The top left panel shows a bar chart visualization of the chat intensity (i.e., the number of characters typed by each student in the text chat), related to that, the right image shows the intensity of chat activities for all students over time. The lower left image illustrates another important feature. A teacher can access the chat text of each student extracted from the entire log file; alongside the competencies assigned to this course are listed with slider controls. These sliders indicate the

```
[Time]
Type=1
WhoS=Old Man
WhoE=granny quest - hint pharmacy
WhatS=Hallo <NAME>, now go there
WhatE=<NAME> got it!
Whom=Johann Wolf; Johanna Wolf; Nick Wolf; Nicole Wolf
MaxTime=5
Up=002
UpVal=0,2
```

Box 1. Example for a time-based rule

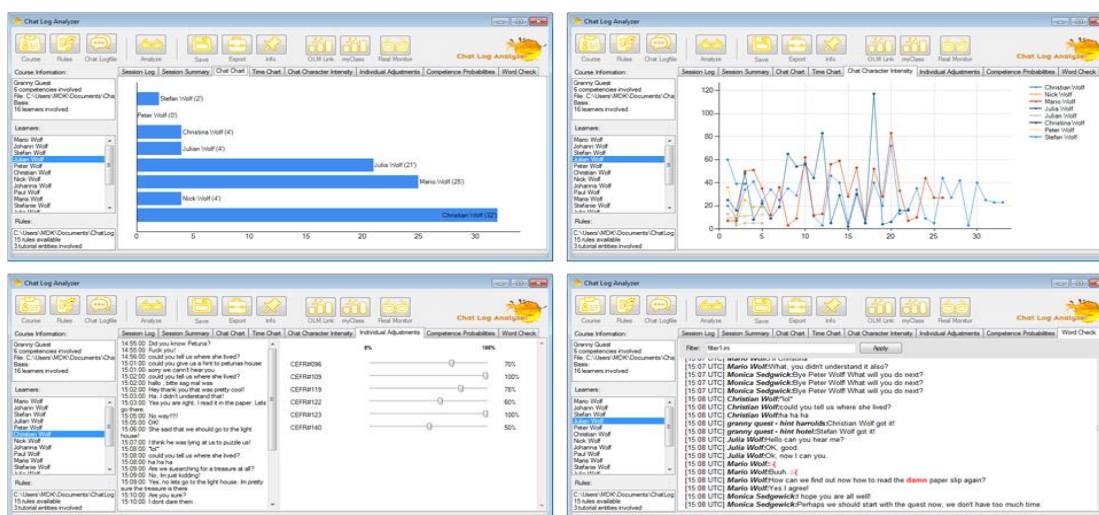


Figure 2. Screenshots of ProNIFA's Chat Log Analyzer

competency level (in a percentage of the likelihood that this competency is available), in a way they mirror the system's adjustments of a student's competency model during the session. A teacher can now, in view of the real chat text, intervene and adjust the competency levels manually.

Finally, the lower right image illustrates another useful feature, namely the filtering and color coding of pre-defined sets of words (e.g., swearwords), phrases, or character combinations (e.g., smiley faces). A teacher can specify any number of such lists and assign colors to them. By applying the filters, the corresponding items immediately pop out of the chat transcript.

This information about the activities and competencies of individual learners as well as of learner groups and the level of an entire class can be used for formatively inspired feedback and interventions through teachers. The described analyses and visualizations are, on the one hand, available after a learning session has been closed; by directly interfacing the logging output from the OpenSim server, on the other hand, the incrementally analyzed information is available in real time also. This enables a teacher to monitor the activities and outcomes in the virtual world on a frequent and continuous basis and to provide real-time feedback or educational interventions when and where necessary. As a concrete example, a teacher could directly help a particular group of learners when she detects that this group is stuck in one of the mini quests. As another example, it is possible for a teacher to identify the competency levels (the probabilities with which students have certain competencies) and to provide individual students with tailored feedback about their current states and also appropriate support and guidance.

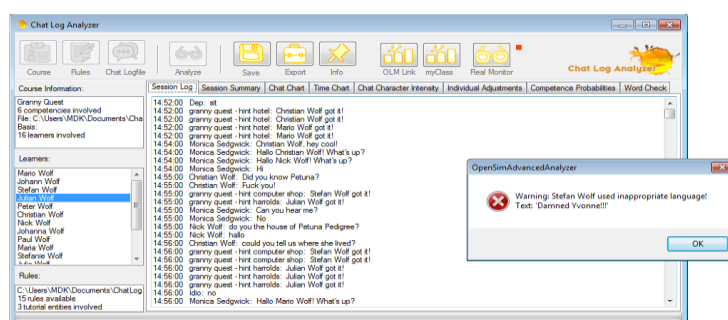


Figure 3. Real-time notifications for teachers

In addition to the post-hoc analyses of the chat log files, the present version of the Chat Log Analyzer features real-time check functionality. As illustrated in Figure 3, a teacher can monitor the entire communication activity in the log window; based on the pre-defined word filters, a teacher can receive warnings in case certain words, phrases, or character combinations are used. Also, if a student, located somewhere in the virtual environment, requests for help, a teacher get an immediate notification. Finally, for the real-time check, the same rule engine as described above, can be applied. By this means, a teacher can specify certain rules (e.g., "if a learner does not

accomplish a certain task within a certain amount of time, I assume she is stuck in a specific quest and needs help”) and if the rule applies, a corresponding notification or warning appears on the screen.

7. Conclusions

There is no doubt that learning scenarios for and in virtual worlds will be a part of classroom education. The advantages are convincing immersion and fun, collaboration and interaction, exploration and active competence construction. At the same time, virtual worlds generate a large amount of educationally relevant information about learners, their strength and weaknesses, the attitudes, activities, and their progress, that can serve as a valuable basis for formative assessment and feedback. The challenge is that teachers need support by smart tools to follow the activities in the virtual world and to be informed about achievements and problems in real time and in an easy to understand and intuitive fashion. ProNIFA is a tool that supports exactly those needs. Moreover, ProNIFA has a scientific, psycho-pedagogical framework in the background enabling a competence and learning performance oriented analysis of data. In addition to the real-time information of teachers, ProNIFA enable the transfer of LA outcomes to more permanent repositories of achievements such as e-Portfolios or, more importantly, OLM platforms. In the context of the Next-Tell project we realized this loop of utilizing virtual worlds for learning on a class level, collecting performance data for LA, providing teachers with suitable information for formative feedback, and to inform the corresponding OLM. The tool is freely available from the authors and it is part of the *nextREALITY* package developed in the context of the Next-Tell project (<http://next-tell.eu/resources/tools/nextreality/>). This package includes pedagogically and conceptual information for setting up educational scenarios in virtual environments as well.

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